THE CASH VALUE OF SCIENTIFIC RESEARCH

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THERE can be no doubt that the average man and woman in Europe and America to-day professes a more or less nebulous feeling of respect and admiration for the scientific investigator. This feeling is not logical, for very few have ever met or seen a scientist, fewer still have ever seen the inside of a scientific laboratory, and hardly any have ever seen scientific research in the making.

The average man in the street or man of affairs has no very clear conception of what manner of man a "scientist" may be. No especial significance attaches in his mind to the term. No picture of a personality or his work arises in the imagination when the word "scientist" is pronounced. More or less indefinitely, I suppose, it is conceded by all that a scientist is a man of vast erudition (an impression by the way which is often strikingly incorrect) who leads a dreary life with his head buried in a book or his eye glued to telescope or microscope, or perfumed with those disagreeable odors which, as everybody knows, are inseparably associated with chemicals. The purpose of this life is not very clear, but doubtless a vague feeling exists in the minds of most of us that people who are willing to pursue such an unattractive career must be worthy of admiration, for despite all the triumphs of commercialism, humanity still loves idealism, even idealism which seems objectless because it is incomprehensible.

From time to time the existence of the scientific man is recalled to the popular mind by some extravagant headlines in the daily press, announcing some utterly impossible "discovery" or some extravagantly nonsensical dictum made by an alleged "scientist." The "discovery" was never made, the dictum never uttered, but no matter; to-morrow its place will be taken by the latest political or matrimonial scandal, and the public, with excellent good sense, will forget all about it.

From time to time, also, there creeps gradually into the public consciousness a sense that *something has happened.* Brief notices appear in the press, at first infrequently and then more frequently, and an article or two in the popular monthlies. The public becomes languidly interested in a new possibility and even discusses it, sceptically. Then of a sudden we are awakened to the realization of a new power in being. The X-ray, wireless telegraphy or the areoplane has become the latest "marvel of science," only to develop in a very brief period into a commonplace of existence.

Many indeed are aware that we owe these "marvels" to scientific research, but very few indeed, to the shame of our schools be it spoken, have attained to the faintest realization of the indubitable fact that we owe almost the entirety of our material environment, and no small proportion of our social and spiritual environment, to the labors of scientists or of their spiritual brethren.

Long ago, in ages so remote that no record of them survives save our heritage of labor well achieved, some pastoral savage, more reflective and less practical than his brethren, took to star-gazing and noting in his memory certain strange coincidences. Doubtless he was chidden by his tribal leaders who were hard-headed men of affairs, skilled in the questionable art of imposing conventional behavior upon unruly tribesmen. But he was an inveterate dreamer, this prehistoric Newton, and the fascination of the thing had gripped his mind. In due time he was gathered to his fathers, but not before he had passed on to a few chosen ones the peculiar coincidences he had observed. And thus, from age to age coincidence was added to coincidence and the result of all this "unpractical" labor was, at long last, a *calendar*. Let who will attempt to estimate the cash value of this discovery; I will not attempt the impossible. I will merely ask you to picture to yourselves humanity in the condition of the Australian Aboriginal or of the South African Bushman; devoid of any means of estimating time or season save by the daily passage of the sun, and I ask you, "supposing that through some vast calamity, a calamity greater even than the present war, humanity could at a stroke evolve a calendar, would it be worth while?" I for one think it would.

The evolution of the calendar is not an inapt illustration of the methods of science, and of the part which it has played in shaping the destiny of man. Out of the unregarded labors of thousands of forgotten men, and a few whom we now remember, has sprung every detail of that vast complex of machinery, method and measurement in which to-day we live and move and have our being. In all ages scientific curiosity guided by the scientific discipline of thought has forced man into new and more complex paths of progress. Lacking the spirit of research, a nation or community is merely parasitic, living upon the vital achievements of others, as Rome based her civilization upon the civilization of the Greeks. Only an indefinite and sterile refinement of the existing environment is possible under such circumstances, and humanity stays stationary or sinks back into the semibarbarism of the middle ages.

The few scattered students of nature of that day picked up the clue to her secrets exactly as it fell from the hands of the Greeks a thousand years before. The foundations of mathematics were so well laid by them that our children learn their geometry from a book written for the schools of Alexandria two thousand years ago. Modern astronomy is the natural continuation and develop-

ment of the work of Hipparchus and of Ptolemy; modern physics of that of Democritus and of Archimedes; it was long before biological science outgrew the knowledge bequeathed to us by Aristotle, by Theophrastus and by Galen.[1]

If, therefore, we ask ourselves what has been the value of science to man, the answer is that its value is practically the value of the whole world in which we find ourselves to-day, or, at any rate, the difference between the value of our world and that of a world inhabited by Neolithic savages.

The sweeping nature of this deduction may from its very comprehensiveness fail to carry conviction to the reader. But concrete illustrations of the value which scientific research may add to our environment are not far to seek. They are afforded in abundance by the dramatic achievements of the past century of human progress, in which science has begun painfully and haltingly to creep into its true place and achieve its true function.

In the year 1813 many important events occurred. The power of Napoleon was crumbling in that year and countless historians have written countless pages describing innumerable events, great and small, which accompanied that colossal downfall. But one event of that year, of which we do not read in our historical memoirs and school books was the discovery by Sir Humphry Davy, in the humble person of a bookbinder's apprentice, of the man who will probably stand out forever in the history of science as the ideal scientific man—Michael Faraday. The manner of this discovery is revealed by the following conversation between Sir Humphry Davy and his friend Pepys. "Pepys, what am I to do, here is a letter from a young man named Faraday; he has been attending my lectures, and wants me to give him employment at the Royal Institution—*what can I do?*" "*Do?*" replied Pepys, "put him to wash bottles; if he refuses he is good for nothing." "No, no," replied Davy; "we must try him with something better than that." The result was, that Davy engaged him to assist in the laboratory at *weekly wages*.[2]

Davy made many important discoveries, but none of his discoveries was more important than his discovery of Faraday, and of all the events which occurred in the year 1813, the entry of Faraday into the Royal Institution was not the least significant for humanity.

On the morning of Christmas day, 1821, Faraday called his wife into his laboratory to witness, for the first time in the history of man, the revolution of a magnet around an electric current. The foundations of electromagnetics were laid and the edifice was built by Faraday upon this foundation in the fourteen succeeding years. In those years and from those labors, the electro-motor, the motor generator, the electrical utilization of water power, the electric car, electric lighting, the

[1] T. H. Huxley, "Science and Culture."

[2] J. Tyndall, "Faraday as a Discoverer."

telephone and telegraph, in short all that is comprised in modern electrical machinery came actually or potentially into being. The little rotating magnet which Faraday showed his wife was, in fact, the first electric motor.

What was the cash value to humanity of those fourteen years of labor in a laboratory?

According to the thirteenth census of the United States, the value of the electrical machinery, apparatus and supplies produced in this country alone, in 1909 was $221,000,000. In 1907, the value of the electric light and power stations in the United States was $1,097,000,000, of the telephones $820,000,000, and the combined income from these two sources was $360,000,000. Nor does this represent a tithe of the values, as yet barely realized, which these researches placed at our disposal. Thus in its waterfalls, the United States is estimated to possess 150,000,000 available horse-power, which can only be realized through the employment of Faraday's electro-motor. This corresponds, at the conservative figure of $20 per horse-power per annum to a yearly income of $3,000,000,000, corresponding at 4 per cent. interest to a capital value of $75,000,000,0000.[3]

Such was the Christmas gift which Michael Faraday presented to the world in 1821.

Faraday died a poor man in 1867, neither for lack of opportunity nor for lack of ability to grasp his opportunities, but because as his pupil Tyndall tells us, he found it necessary to choose between the pursuit of wealth and the pursuit of science, and he deliberately chose the latter. This is not a bad thing. It is perhaps as it should be, and as it has been in the vast majority of cases. But another fact which can not be viewed with like equanimity is that of all the inexhaustible wealth which Faraday poured into the lap of the world, not one millionth, not a discernible fraction, has ever been returned to science for the furtherance of its aims and its achievements, for the *continuance* of research.

There is no regular machinery for securing the permanent endowment of research, and it is always and everywhere a barely tolerated intruder. In the universities it crouches under the shadow of pedagogy, and snatches its time and its materials from the fragments which are left over when the all-important business of teaching the young what others have accomplished has been done. In commercial institutions it occasionally pursues a stunted career, subject to all the caprices of momentary commercial advantage and the cramped outlook of the "practical man." The investigator in the employ of a commercial undertaking is encouraged to be original, it is true, but not to be *too* original. He must never transcend the "practical," that is to say, the

[3] M. T. Bogert, "The Function of Chemistry in the Conservation of our National Resources," *Journal of the American Chemical Society*, February, 1909.

infinitesimal rearrangement of the preexisting. The institutions existing in the world which are devoted to research and research alone can almost be counted on the fingers. The Solvay Institute in Brussels, the Nobel Institute in Stockholm, the Pasteur Institute in France, the Institute for Experimental Therapy at Frankfort, The Kaiser Wilhelm Institutes at Berlin, The Imperial Institute for Medical Research at Petrograd, the Biologisches Versuchsanstalt at Vienna, the Biological Station at Naples, the Royal Institution in London, the Wellcome Laboratories in England and at Khartoum, the Smithsonian, Wistar, Carnegie and Rockefeller Institutes in the United States; the list of research institutes of important dimensions (excluding astronomical observatories) is, I believe, practically exhausted by the above enumeration, and many of them are woefully undermanned and underequipped. At least two of them, the Solvay Institute wholly, and the Frankfort Institute for Experimental Therapy in part, owe their existence and continuance to scientific men, Solvay and Ehrlich, who have contrived to combine the pursuit of wealth and of science, and have dedicated the wealth thus procured to the science that gave it birth.

In 1900 the value of the manufacturing industries in the United States which had been developed from patented scientific inventions was no less than $395,663,958 per annum,[4] corresponding to a capital value of about $10,000,000,000. It is impossible to arrive at any accurate estimate of the proportion of this wealth which finds its way back to science to provide equipment and subsistence for the investigator, who is creating the wealth of the future. But the capital endowment of the Rockefeller and Carnegie Institutes, the two wealthiest institutes of research in the world is, according to the 1914 issue of *Minerva*, only $29,000,000. The total income (exclusive of additions to endowments) of all the higher institutions of learning in the United States in 1913, was only $90,000,000, of which a minute percentage was expended in research.

If science produces so much wealth, is there no contrivance whereby we can cause a small fraction of this wealth to return automatically to science and to furnish munitions of war for fresh conquests of nature? A very small investment in research often produces colossal returns. In 1911 the income of the Kaiser Wilhelm Institute for Physical Chemistry was only $21,000. In 1913 the income of the Institute for Experimental Therapy at Frankfort, where "606" was discovered, was only $20,000; that of the Imperial Institute for Medical Research at Petrograd was $95,000, and that of the National Physical Laboratory in England (not exclusively devoted to research) was $40,000. Yet these are among the most famous research institutions in the world and have achieved results of world-wide fame and inestimable value both

[4] 12th census, Vol. 10, Part 4.

from a financial standpoint and from the standpoint of the physical, moral and spiritual welfare of mankind.

In 1856, Perkin, an English chemist, discovered the coal-tar (anilin) dyes. The cost of this investigation, which was carried out in an improvised, private laboratory was negligible. Yet, in 1905, the United States imported $5,635,164 worth of these dyes from Europe, and Germany exported $24,065,500 worth to all parts of the world.[5] To-day we read that great industries in this country are paralyzed because these dyes temporarily can not be imported from Germany. All of these vast results sprang from a modest little laboratory, a meager equipment and the genius and patience of one man.

W. R. Whitney, director of the research laboratory of the General Electric Company, points out that the collective improvements in the manufacture of filaments for electric lamps, from 1901 to 1911, have saved the consumer and producer no less than $240,000,000 annually. He adds with apparently unconscious naïveté that the expenses of the research laboratory in his charge aggregate more than $100,000 annually![6] A handsome investment, this, which brings in some two hundred million for an outlay of one hundred thousand.

According to Huxley the discovery by Pasteur of the means of preventing or curing anthrax, silkworm disease and chicken cholera, a fraction of that great man's life work, added annually to the wealth of France a sum equivalent to the entire indemnity paid by France to Germany after the war of 1870.

Humanity has not finished its conquest of nature; on the contrary, it has barely begun. The discipline of thought which has carried humanity so far is destined to carry it further yet. Business enterprise and politics, the all-absorbing interests of the majority of mankind, work in an endless circle. Scientific research communicates a thrust to this rotation which converts the circle into a spiral; the apex of that spiral lies far beyond our vision. We have, not decades, not centuries, not thousands of years before us; but, as astronomy assures us, in all probability, humanity has millions of years of earthly destiny to realize. Barely three thousand years of *purposeful* scientific research have brought the uttermost ends of the earth to our doors; have made civilization and excluded much of the most brutal and brutalizing in life. Not more than two hundred years of research have made us masters where we were slaves; masters of distance, of the air, of the water, of the bowels of the earth, of many of the most dreaded aspects of disease and suffering. Only for forty years have we practised antisepsis; only for sixty years have we had anesthetics; yet life to-day is well-nigh inconceivable without them. And all of this has been accomplished

[5] U. S. Census Bureau Bull. 92.

[6] "Technology and Industrial Efficiency," McGraw-Hill Book Co., 1911.

without any forethought on the part of the acknowledged rulers and leaders of mankind or any save the most trumpery and uncertain provision for research. What will the millions of years which stretch in front of us bring of power to mankind? We can barely foreshadow things too vast to grasp; things that will make the imaginings of Jules Verne and H. G. Wells seem puny by comparison. The future, with the uncanny control which it will bring over things that seem to us almost sacred—over life and death and development and thought itself —might well seem to us a terrifying prospect were it not for one great saving clause. Through all that may happen to man, of this we may be sure, that he will remain human; and because of that we can face the future unafraid and confident that because it will be greater, it will also be better than the present.

What can we do to accelerate the coming of this future? Not very much, it is true, but we can surely do something. We can not create geniuses, often we can not discern them, but having discerned, surely we can use them to the best advantage. It is true that all scientific research has depended and will depend upon individuals; Simon Newcomb expresses the matter thus:

> It is impressive to think how few men we should have to remove from the earth during the past three centuries to have stopped the advance of our civilization. In the seventeenth century there would only have been Galileo, Newton and a few other contemporaries, in the eighteenth they could almost have been counted on the fingers, and they have not crowded the nineteenth.[7]

The first thing we have to do is to discover such men, to learn to know them or suspect them when we meet them or their works. The next is to give them moral and financial recognition, and the means of doing their work. Our procedure in the past has been the reverse of this. I quote from a letter of Kepler to his friend Moestlen:

> I supplicate you, if there is a situation vacant at Tübingen, do what you can to obtain it for me, and let me know the prices of bread, wine and other necessaries of life, for my wife is not accustomed to live on beans.

The founder of comparative psychology, J. H. Fabre, that "incomparable observer" as Darwin characterized him, is now over ninety years of age, and until very recently was actually suffering from poverty. All his life his work was stunted and crippled by poverty, and countless researches which he was the one human being qualified by genius and experience to undertake, remain to this day unperformed because he never could command the meager necessary equipment of apparatus.

Once again, what can we do?

No small proportion of the population of a modern community are alumni of some institution of higher learning, and one thing that these

[7] "Inventors at Work," Iles, Doubleday Page, 1906.

can do is to see to it by every means in their power that some measure of the spirit of academic freedom is preserved in their alma mater. That the spirit of inquiry and research is not merely tolerated therein but fostered and substantially supported, morally and financially.

As members of the body politic, we can assist the development of science in two ways. *Firstly,* by doing each our individual part towards ensuring that endowment for the university must provide not only for "teaching adolescents the rudiments of Greek and Latin" and erecting imposing buildings, but also for the furtherance of scientific research. The public readily appreciates a great educational mill for the manufacture of mediocre learning, and it always appreciates a showy building, but it is slow to realize that that which urgently and at all times needs endowment is experimental research.

Secondly, it is vital that public sentiment should be educated to the point of providing the legal machinery whereby some proportion, no matter how small, of the wealth which science pours into the lap of the community, shall return automatically to the support and expansion of scientific research. The collection of a tax upon the profits accruing from inventions (which are all ultimately if indirectly results of scientific advances) and the devotion of the proceeds from this tax to the furtherance of research would not only be a policy of wisdom in the most material sense, but it would also be a policy of bare justice.